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The Navruz experiment: Cooperative monitoring for radionuclides and metals in Central Asia transboundary rivers

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In March of 2000, scientists from four nuclear physics research institutes in the Central Asia Republics of Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan, and the U.S. Sandia National Laboratories embarked on a three-year cooperative transboundary river monitoring experiment. The experiment, named Navruz (meaning "new beginning"), uses standardized methods to monitor basic water quality parameters, radionuclides, and metals in the Syr Darya and Amu Darya rivers. Overall, the project addresses three main goals: (1) to help increase capabilities in Central Asian nations for sustainable water resources management; (2) to provide a scientific basis for supporting nuclear transparency and non-proliferation in the region; and (3) to help reduce the threat of conflict in Central Asia over water resources. Contamination of these rivers is a result of growing population, urbanization, agricultural uses, and radioactive and metals contamination from a legacy of uranium mining, industry, and other activities of the former Soviet Union. The project focuses on waterborne radionuclides and metals because of the importance of these contaminants to public health and political stability in Central Asia. Moreover, the method of enabling scientists from bordering countries to study a transboundary problem, can lead to a greater scientific understanding, consensus on necessary mitigation steps, and ultimately the political resolution of the issue. The project scope, approach, and preliminary results are presented.

Introduction

Although it was recognized as an important geopolitical area prior to the terrorist attacks of September 11, 2001, the Central Asia region has gained significant additional publicity and recognition since then. Surrounded by the nuclear-weapon states of Russia and China and bordering on Afghanistan and Iran, this region is now identified as an increasingly important geopolitical area. The countries of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan established their independence after the fall of the Soviet Union. Although enjoying their first liberty since the time of Catherine the Great, these new states are beset with the same problems that existed during the Soviet time. However, lacking the centrally directed unifying power of the old Soviet state, these countries have had limited cooperation with their neighboring states toward resolving those regional issues. This lack of cooperation could result in conflicts among the countries over ethnic differences, unresolved border delineation, terrorist movements, trafficking of illicit materials, and scarcity of natural resources.

One major issue of Central Asia is the scarcity of clean water for human consumption, agriculture, and industry. Although the bordering Caspian Sea region is thought to hold perhaps the world's second largest supply of oil and natural gas, most people in Central Asia are dependent upon the rivers of the Aral Sea basin to provide their living. Threatening these supplies are the ambitious, but ill conceived and shortsighted Soviet plans to greatly expand the irrigation system to grow cotton, and a legacy of industry, agricultural, and mining methods that greatly reduced the available water supply and contaminated the rivers.

The Navruz Project was created to bring scientists together from the various countries of Central Asia to understand and help resolve regional issues. Navruz means "new beginning" and was coined as the project name by the participants as aptly representative of their newborn collaboration together. Collaboration at the scientific level is aimed at enhancing regional cooperation and thus, promoting regional security. By using contacts in each country's national academy of sciences, scientists from four countries in the region were brought together for the first time in March 2000 for a workshop at the Institute of Nuclear Physics near Tashkent, Uzbekistan.

Regional differences surfaced in just this small initial step. For example, the scientists from Tajikistan had difficulty traveling to the conference. There was no air service from Dushanbe to Tashkent, and Uzbekistan would not allow a private vehicle from Tajikistan to cross the border. The delegation from Kazakhstan was also not able to fly to the meeting since Kazakhstan and Uzbekistan were disagreeing on the cost of aviation fuel.

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Both groups resolved this barrier by driving their cars to the border, walking across with their baggage, and securing transportation on the other side. Scientists from Turkmenistan did not attend due to differences between two Turkmen ministries.

Although the workshop held in March 2000 exemplified regional difficulties, it also exemplified a fine example of regional cooperation and demonstrated a commitment to work together despite possible barriers. The participants agreed to work together to survey the extent of the radionuclide and metals contamination in the major transboundary rivers, in particular, the Syr Darya and Amu Darya. The United States Sandia National Laboratories (SNL) also agreed to collect samples from two sites on the Rio Grande near Albuquerque to show a degree of openness and transparency among the countries. To ensure commonality of data, standards and methods were created for the collection of samples, laboratory analysis, and sharing of all project data. Some results of this investigation are presented in this paper and in companion papers written by each participating institutes' scientists for the MARC-VI conference. Perhaps of more significance is the cooperation gained in developing the standard methodology and demonstrating that country differences can be overcome in the common effort to resolving regional problems.

Methodology

The initial workshop for this project was held at the Uzbekistan Institute of Nuclear Physics just outside Tashkent in March 2000. The participants included the nuclear physics institutes in Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan, the Center for Non-proliferation Studies of the Monterey Institute of International Studies, and the Cooperative Monitoring Center (CMC) at SNL. Due to concern for river contamination caused by former Soviet policies, the participants chose to perform an initial survey of the amount and type of radioactive and metals contamination at 60 monitoring sites (15 in each country) on the major rivers and tributaries of the Aral Sea basin. These sites were selected by each country's representatives because of proximity to past uranium mining, industrial activity, or population center. The monitoring sites are shown in Fig. 1.

Each Central Asia institute collected samples within its own country. Kazakhstan and Uzbekistan have laboratories capable of analyzing for 71 radionuclides (including the uranium and thorium series) and 25 metals.[1] Instruments included alpha- and beta-counters, gamma-spectrometers, neutron activation analysis (NAA), and inductive-coupled plasma atomic emission spectrometers (AES-ICP).[1] NAA is conducted at the Kazakhstan laboratory by use of the VVR-K research reactor. Both laboratories meet International Atomic Energy Agency (IAEA) standards. SNL was responsible for quality assurance, and each Central Asia institute shipped approximately 10% of duplicate samples to SNL for QA analyses.[1]

Basic water parameters were also collected by use of field-portable water quality monitoring equipment. At each site, the following parameters were measured in situ: water temperature, specific conductivity, oxidation-reduction potential, pH, dissolved oxygen (DO), salinity, and total dissolved solids (TDS).[1] These data are useful in understanding the chemistry involving the suspended and deposited radionuclides and metals. Discharge data (flow velocity and volume) during each sampling trip proved a difficult parameter to measure, since the collection sites were very diverse and physically challenging. Upstream in Kyrgyzstan and Tajikistan, the rivers are shallow and fast flowing. In the downstream countries of Kazakhstan and Uzbekistan, the rivers are broad, deep, and slow. Some methods of measuring discharge included the use of a mechanical current meter and approximating the contour of the riverbed, the use of a "pitot" tube developed by Dr. Akram DJURAEV, our Tajik principal investigator, and finally, obtaining data from nearby weirs that were constructed during the Soviet time.[2] In some cases, the specific site conditions prevented obtaining discharge data.

It was necessary to establish a common set of standards and methods for sample collection, since participating institutes had different methods and approaches. At each site, samples of filtered and unfiltered water, bottom sediment, aquatic vegetation, and adjacent riverbank soils were collected. Since collection would occur in four countries and five different media, standard methods for packaging, labeling, transport, and shipping of the samples were also developed. All agreed standards for sample collection and laboratory analysis were published in the Sampling and Analysis Plan and Operational Manual.[1]

SNL held training sessions during the workshop in August 2000 for the field technical participants from each country. Training included the operation and maintenance of the portable field water quality sensor and the USGS method for determining discharge. The field technicians were also shown how to complete the field logs and the agreed sample collection procedures were demonstrated. A day-long practical exercise was held at a site on the Chirchik River near the Uzbekistan Institute of Nuclear Physics on the final training day.

No.	Kyrgyzstan	No.	Kazakhstan	No.	Tajikistan	No.	Uzbekistan
01	Kichi-Naryn River	16	Chardarya reservoir, southeastern coast	31	Varzob River, above Dushanbe	46	Amudarya, Kyzyldzhar village
02	Chong-Naryn River	17	Chardarya reservoir, northeastern coast	32	Varzob River, below Dushanbe	47	Amudarya, Kipchak town
03	Naryn River before Kichi-Naryn confluence	18	Keles River, Saryagash town (upstream)	33	Kafirnigan River, above Varzob River confluence	48	Amudarya, Tuyamuyun site
04	At-Bashy River	19	Keles River, Saryagash town (downstream)	34	Kafirnigan River, below Elok River confluence	49	Karadarya, Kol' village
05	Naryn River after At-Bashy confluence	20	Badam River, Chymkent	35	Kafirnigan River, Shaartuz bridge	50	Syrdarya, Bekabad
06	Chychkan River before Toktogul reservoir	21	Arys River, near Obruchevka	36	Elok River	51	Syrdarya, Chinaz town
07	Naryn River, before Toktogul reservoir	22	Syrdarya, Chernak village	37	Vakhsh River, Dzhilikul bridge	52	Ankangaran River, Yangiabad town
08	Toktogul reservoir	23	Syrdarya, Tomlnaryk village	38	Vakhsh River, Chiluchor spring	53	Akhangaran River, Angren town
09	Naryn River after Toktogul reservoir	24	Syrdarya, Shyily	39	Yekhsu River, settlement Vose	54	Akhangaran River, Tuyabuguz
10	Naryn River, Tashkumyr	25	Syrdarya, Zhulek village	40	Yekhsu River, settlement Vose	55	Chirchik River, Gazalkent town
11	Mailuu-Suu River, at Uzbekistan border	26	Syrdarya, Belkul village	41	Kyzylsu River, settlement Vose	56	Chirchik River, Kibraj village
12	Mailuu-Suu River, Mailuu-Su town	27	Syrdarya, Abaj village	42	Kyzylsu River, Gulistan village	57	Chirchik River, Tashkent City
13	Mailuu-Suu River near transformer factory	28	Syrdarya, Korkyt village	43	Syrdarya, settlement Bulok	58	Zaravshan River, Ravatkhodzha
14	Mailuu-Suu River, right tributary	29	Syrdarya, below Torwtam village	44	Syrdarya, Khudzhand city	59	Zaravshan River, Kattakurgan
15	Mailuu-Suu River	30	Syrdarya, Kazalinsk	45	Isfara River	60	Zaravshan River, Navoi City

Fig. 1. Map of Navruz Project sampling sites[1]

Results

The Navruz 1 Project gathered five types of samples from 60 sites over three different periods (two autumn and one spring) in 2000 and 2001. All samples were analyzed at the participating project partners' laboratories in Kazakhstan and Uzbekistan. The results of these analyses are found on the SNL/CMC World Wide Web site.[4]

The activities of radionuclides from three natural families (uranium, thorium, and actinoruranium), the natural radionuclide ^{40}K, and the artificial radionuclides ^{137}Cs and ^{241}Am were measured. Complete results containing all sampling and analysis data can be found in the Navruz Project Data Report.[3] As expected, higher concentrations of radionuclides were found in the vegetation and bottom sediment samples. Metals concentration data were determined through neutron activation analysis in the 10 MW VVR research reactors of both laboratories.[1]

Preliminary analysis indicated a very high content of selenium in the entire investigated region of the Syr

Darya.[2] The concentration of this element in water arouses concern, as it exceeds health sanitary standards of maximal tolerant concentrations (MTC-1 micrograms per liter) for drinking water by 1.5 to 4 times.[2] Additionally, salt content of both the Syr Darya and Amu Darya more than doubled during their travels toward the Aral Sea. The source of the salt is not known, but is perhaps the result of naturally occurring elements and/or its concentration due to agricultural return flows from irrigation.

An example of natural radionuclide distribution in riverbank soils and bottom sediments from upstream to downstream along the Syr Darya in Kazakhstan is presented in Fig. 2. Figure 2 should be viewed as preliminary results with relative values. Uncertainly values are not presented, but detection limits can be found in the Sampling and Analysis Plan.[1] Smaller sample location numbers represent upstream locations. The largest concentration of natural radionuclides in bottom sediments corresponds to sites in Kazakhstan at the southeastern part of the Chardarya Reservoir in Fig. 1, site 16.[2] Probable explanations for this concentration are the hydrogeological and geomorphic properties of this location from water to bottom sediments, and uranium deposits and industry effects from upstream. There are also increased concentrations of all natural radionuclides and uranium deposits near the city of Shyily in Fig. 1, sites 23–25. Other anomalies require further investigation.

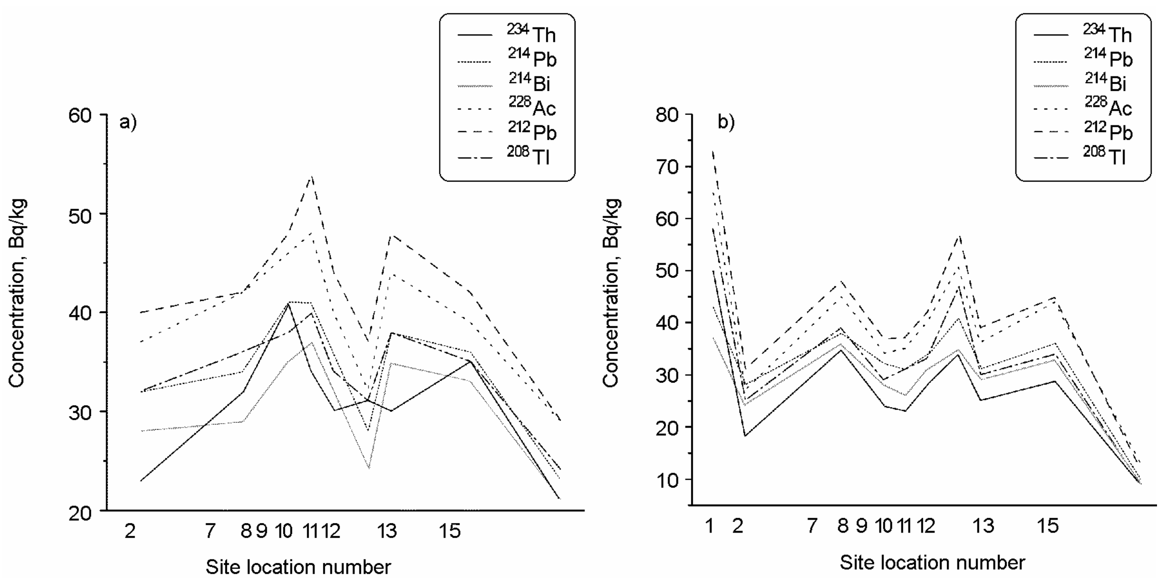

Fig. 2. Distribution of natural radionuclides (^{238}U and ^{232}Th families) along the Syr Darya River in Kazakhstan;[2] (a) soil, (b) bottom sediments

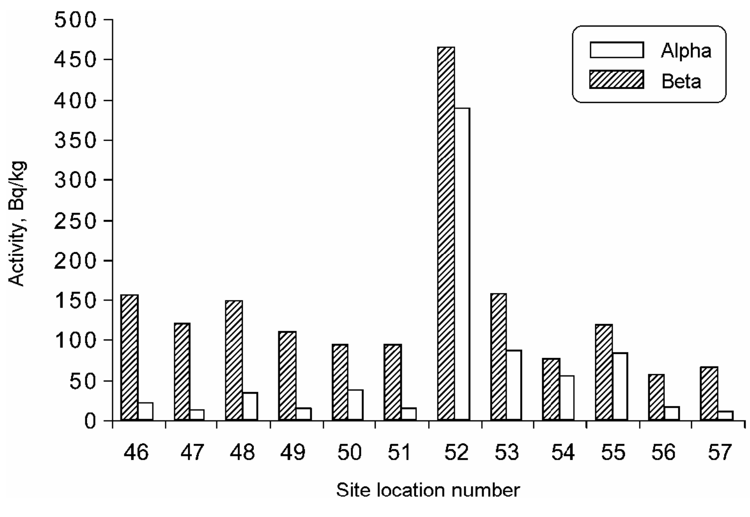

Fig. 3. Radioactivity of vegetation, from various Uzbekistan rivers[2]

Another example of radionuclide distribution is from the Akhangaran River sites in Uzbekistan in Fig. 1, sites 52–54. The Akhangaran River is a tributary of the Syr Darya in the Ferghana Valley, not far from Tashkent. Alpha and beta measurements from vegetation showed significantly increased activity at the Uzbekistan site 52, as shown in Fig. 3. The highest concentrations of natural radionuclides in riverbank soil and bottom sediments in the project were also detected in samples from the Akhangaran River near the cities of Yangiabad, Angren, and Tuyabuguz in Fig. 1, sites 52–54. The concentration of the radionuclides of the ^{238}U and ^{232}Th families frequently exceeded 100 Bq/kg. This is probably due to former uranium mines upstream, but still within Uzbekistan.

In Tajikistan, the highest concentration of natural radionuclides in the ^{238}U and ^{232}Th families is found on the Syr Darya near Khudzhand City in Fig. 1, site 44, also in the Ferghana Valley.[2] Additionally, the highest contamination by ^{137}Cs in the region was found in the rivers that are tributaries to the Amu Darya fed from the glaciers from the Pamir mountain range of eastern Tajikistan.[2] The source of this contamination requires further investigation.

Being an upstream country and a major source of the Syr Darya, Kyrgyzstan enjoys relatively low levels of contamination by radionuclides and metals compared with its downstream neighbors. However, considerably higher levels of radionuclide contamination were found downstream from the Mailuu-Su uranium tailings site compared to just upstream. The Mailuu-Su River in Fig. 1, sites 11–15, is a tributary to the Syr Darya near the Ferghana Valley, a critical agricultural and industrial area in Uzbekistan and Tajikistan.[2] A fear is that a catastrophic event, such as heavy rainfall or earthquake, could wash these tailings into the river resulting in significant contamination downstream.

Conclusions

The Navruz Project surveyed the radionuclide and metal contamination at 60 selected sites in the Aral Sea basin. The results indicated in this paper should be considered as preliminary. Further work is required to characterize sites of interest and understand the amount and sources of contamination. Additionally, there is a need to conduct a risk assessment of contamination to the downstream population, agriculture, and industry.

The monitoring sites of the Project were selected by each participant's institute because of a need for information on environmental contamination. This study indicates several sites that require further investigation. It also indicates locations that do not contain sufficient contamination to warrant detailed examination. Therefore, as intended, this initial survey across the major rivers of the Aral Sea basin can also be considered a baseline for further river contamination examinations.

Of greater overall project significance is that the methodology of this research can be a model and process to cooperative investigation and possible resolution of issues between countries within a region. In this case, scientists from four neighboring countries participated together to understand a regional concern, the radionuclide and metals contamination of their transboundary rivers. This examination was conducted in a spirit of cooperation and without regard for national differences. The data were collected and analyzed in an agreed standard methodology, and the results shared among all the scientists. As a result, the project was stronger and richer due to the combined differences and ideas of the project partners.

This project's goals were scientific as well as confidence building. Since these regional countries are very concerned about these vital water resources and since the project partners worked closely in a joint collaboration, this project demonstrates a cooperative method to manage these important Aral Sea basin rivers.

Through the support of the U.S. Department of Energy, the U.S. Department of State, the International Science and Technology Center (ISTC), and the Science and Technology Center Ukraine (STCU), the follow-on project, Navruz 2, is beginning. This project will again rely on the collaboration of the national institutes as in Navruz 1 and seeks to characterize several sites in and near the Ferghana Valley that have shown significantly higher levels of radionuclide and metals contamination. The sources of the contamination will be traced using radioisotope analysis. From these analyzes, risk to the population, agriculture, and industry can be assessed. Other projects using this type of collaboration should be developed with the goal of cooperative study and management of this important river basin.

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